design robots with your PC

Lego Robotics Invention System

By H. Steeman

The Lego Robotics Invention System has been available for a while already. This system enables every computer hobbyist to design, build and above all program robots to his heart's content.

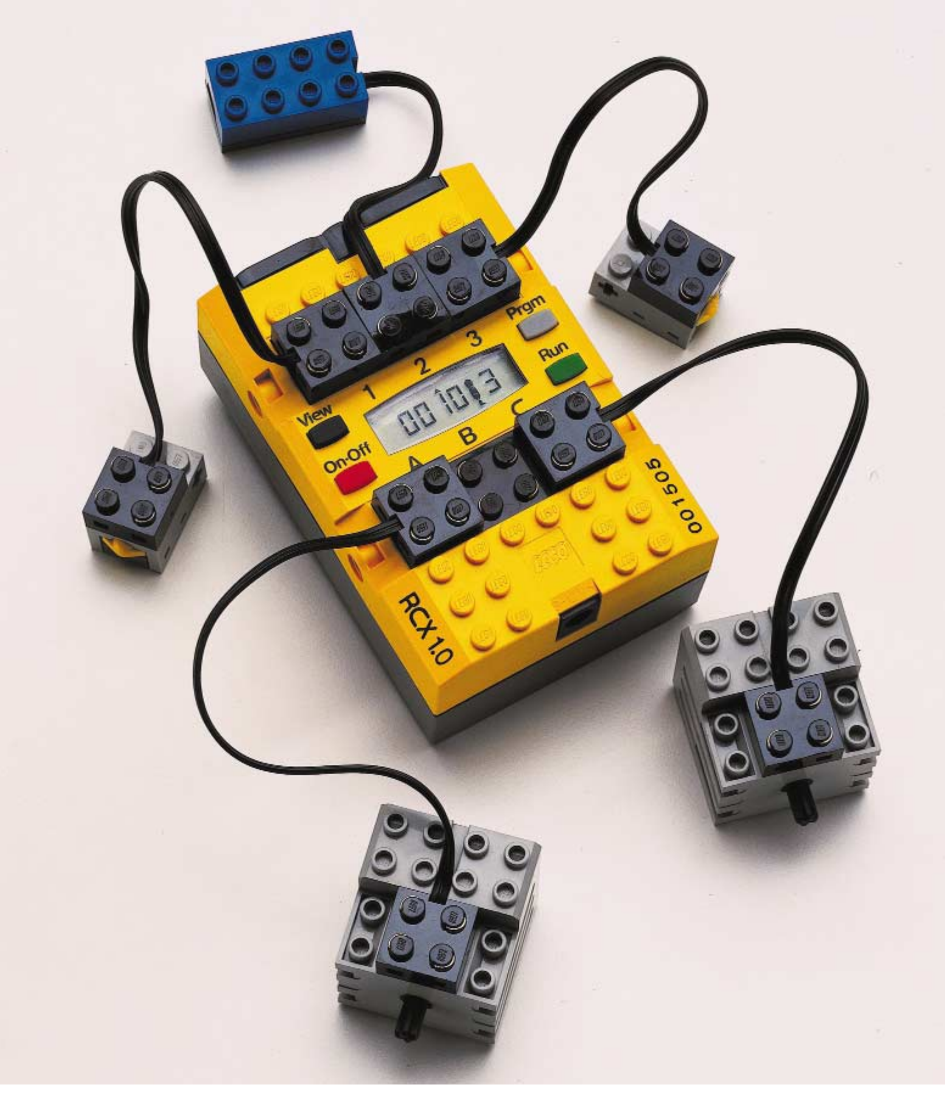


Figure 1. The RCX module is an innovative Lego block, packed full with electronics, that allows intelligent models to be built.

This kit contains more than seven hundred pieces, including an intelligent module (RCX) that can be programmed wirelessly from the PC. This is a wonderful robot system for any hobbyist or PC fan. And of course it's only fitting that we at *Elektor Electronics* should devote considerable attention to this development. Robots in general, and the Lego system in particular, will be featured in the coming months.

Long-term development

The development of the intelligent module that forms the heart of the robot development system was not an overnight affair. Lego devoted more than ten years in total to the realisation of the design of this module. After the system first appeared on the market in America around one year ago, a number of improvements were made. This made it possible to introduce a polished product into the European market in 1999. The design and capabilities of the intelligent module, which Lego calls the RSX 1.0, have received a lot of admiring and respectful attention. The NASA Discovery mission STS-96 even carried a robot

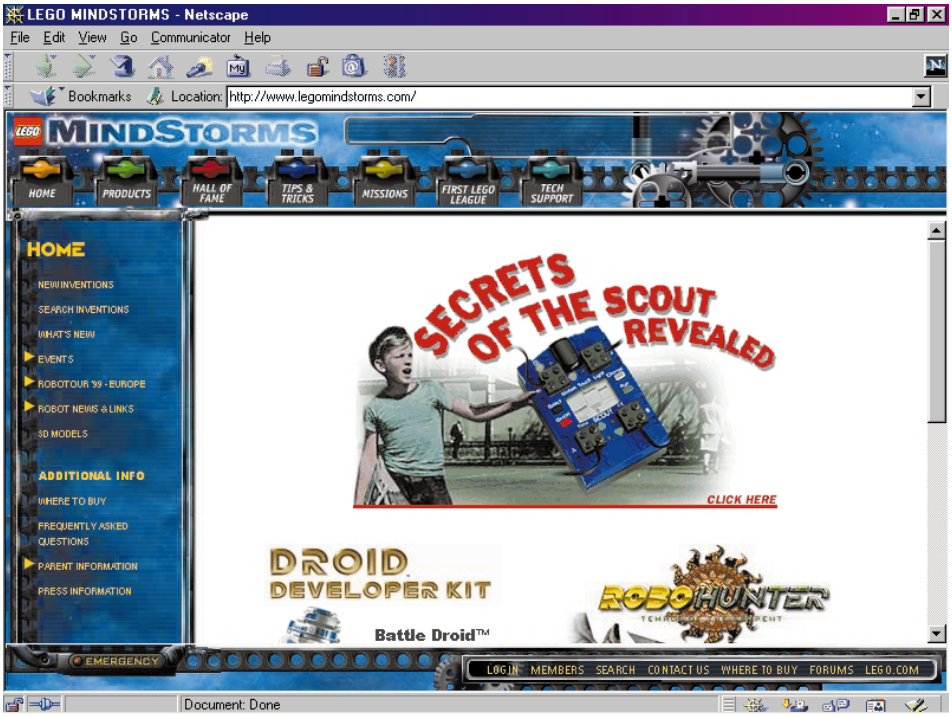


Figure 2. An Internet portal has been set up especially for the MindStorms systems. Users can exchange experience and programs via this site.

System requirements

The PC to be used must meet a certain number of requirements. The operating system should be Windows 95 or 98, and the system must have an 8× CD-ROM drive, a Pentium processor (166 MHz), an SVGA video card (800 x 600 pixels and 1 MB of video memory) that supports DirectX, a 16-bit SoundBlaster-compatible sound card, a 9-pin serial port and at least 16 MB of working memory. There must be at least 70 MB of free space on the hard disc drive. Every standard PC model should have no trouble meeting these requirements. For optimum use of the RIS, access to the Internet is necessary.

built using the Robot Invention System as a supplementary payload. This came about as part of a project to stimulate the interest of young people in information technology.

The developers of the RCX module worked together with employees of the Media Lab of the Massachusetts Institute of Technology in the course of the development project.

There is broad international admiration for the Lego concept. This system, which is based on ABS plastic building blocks produced by the Danish Lego company, was recently named the product of the century by the leading American journal *Fortune Magazine*. With the introduction of the Robot Invention System (RIS for short), which by the way is part of the much larger Lego MindStorms program, Lego has brought an entirely new dimension to the use of PCs. A PC owner can use these kits in a very adult and professional manner to build robots that can execute up to five programs and are able to react to stimuli from their surroundings. The programs can be written using a graphic programming environment specially developed by Lego, as we will see in subsequent articles. An advanced programmer can also program the RCX module using a professional programming environment such as Visual BASIC, Visual C++ or Delphi. The necessary library of basic routines has been published on the Internet.

The sensors currently available include contact sensors (miniature switches built into Lego blocks), a combined light sensor and reflective sensor, a rotation counter for measuring distances and a temperature sensor. It is thus possible to sense analogue ambient variables, such as the temperature of the surroundings and variations in light intensity, as well as digital values such as contact/no contact. The RCX module has an infrared communication port that can be used transfer information between the module and a PC. This port can also be used to allow several RCX blocks to communicate with each other.

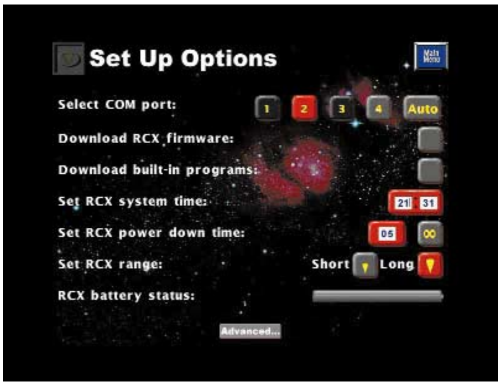
Each RCX module has three pulse-width modulated outputs that can be used to actuate motors and lamps. An integrated buzzer can be used to generate an audible signal. There is also a built-in liquid-crystal display to provide information to the user. Figure 1 shows an RCX module that is connected to two motors and three sensors. One of the outputs of the RCX module shown in the photo is not used.

The Robotics Invention System combines the strength of Lego, which is providing components that can be used to build mechanical constructions, with the intelligence of microelectronics and the computational power of the PC. The Internet has also been brought into play, in order to provide users of the RIS with a common meeting point in the form of a dedicated 'portal'. This is located at the web address *http://www.legomindstorms.com*.

What's in the box?

The yellow RCX module is the most eye-catching part of the kit. This oversized Lego block still has some resemblance to the famous standard Lego block, and it also can be built into the models in the same manner as a conventional block. It contains a complete microcomputer system with its own operating system, which can be downloaded from a PC.

The heart of this system is a 64-pin Hitachi microcontroller from the H8 family, which works with a 16 MHz clock. The microcontroller has 16 kB of internal ROM and is supported by 32 kB of RAM.



Select COM port: 1 2 3 4 Auto
Download RCX firmware:
Download built-in programs:
Set RCX system time: 21 31
Set RCX power down time: 05 ∞
Set RCX range: Short Long
RCX battery status:

Figure 3. The PC software shows the user everything that the system can do.

The RAM has a battery supply with a limited backup function. As long as the six penlight batteries (normal or rechargeable) supply power, the program is held in the memory. The content of the memory is retained for one minute without power while the batteries are being replaced, but it is lost if power is absent for longer than one minute.

The 16-kB ROM contains the basic routines, such as a bootstrap loader that is needed to cold-start the module. It is not possible to run user-written programs directly after a cold start, since the operating system is not present. The built-in software can however activate any connected motors and support the built-in infrared port. The user can see that the module is in this basic mode by the fact that the display shows only an icon representing a standing person, followed by a number between 1 and 5.

The built-in software starts working after it receives support in the form of the RCX operating system, which can be downloaded from a PC. The operating system uses 16 kB of the RAM, so there is 16 kB left for user-developed programs. Since the RCX module utilises a byte-oriented code that is a sort of machine language with around 70 instructions, this is adequate for even the most extensive applications. The RCX operating system is event-oriented and can execute up to six tasks in parallel.

In addition to the H8 processor and the memory chips, the RCX block contains a compact graphic LCD, a miniature loudspeaker (15 mm diameter), an LCD controller, a voltage regulator, two infrared transmitter diodes, a photodiode and a number of passive components.

Figure 4. With an extension kit, you can even recreate the well-known R2D2 robot from the Star Wars films in your own living room.

IR transceiver

The RCX module communicates with the PC via an infrared transmitter/receiver module that is connected to the serial port of the PC with a 9-pin connector. This module is powered by a 9-V battery. Only the TxD, RxD and GND lines of the serial port are used. There is thus no handshaking present.

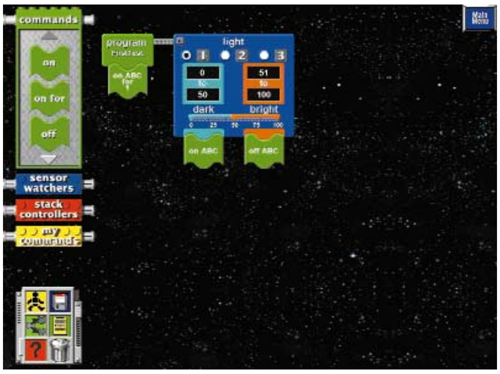


Figure 5. The RCX module can be completely configured using this screen. The operating system is also downloaded to the RCX module using the menu.

The RTS and CTS pins are shorted together in the IR transceiver. The software can tell whether the module is present by using two of the five interface lines to detect the connection between these two signal lines. There is currently no USB version of the transceiver available, but one presumably will come. Once this version is available, users of Apple Macintosh computers will also be able to work with the Robotics Invention System.

A switch on the front of the module can be used to select a short or long transmission range. In actual use, the module can faultlessly handle a range of several metres.

As soon as the RCX module has been switched on, the infrared transceiver has been connected to a free serial port of the PC and the software on the accompanying CD-ROM has been installed, the system is ready to use. The first action is to download the RCX operating system. This extra step may appear to be inconvenient, but it has the important advantage that the software can be improved and extended in the future. The version supplied with the kit, for example, already incorporates support for the rotary sensor, the temperature sensor and two types of sensors that are not included in the basic kit.

There are by the way other versions of the RCX module available, which are called the Scout and the MicroScout. The Scout is used in the Robotics Discovery Set, which Lego will probably introduce in Europe later this year. This system can only be controlled by a keypad on the Scout module, and is thus more suitable for beginners. It does not come with an infrared interface to the PC. An extension of the Scout module to enable it to be programmed via the PC is presently being developed, and this possibility is already incorporated into the basic system design. The MicroScout module is used in the Droid Developer Kit, which can be used to build models from the Star Wars films such as R2D2 Astromech Droid. The MicroScout contains seven built-in programs that cannot be modified by the user. The Droid Developer Kit can be used as an extension to the Robotics Invention Kit and is available in Europe.

Getting down to work

Once the operating system has been downloaded into the RCX module, a little man icon appears on the display to indicate that the RCX module is ready for use. Now you can start the software on the PC and enter the realm of the robot designer.

Worked-through examples are provided to guide you through the construction of a number of simple robots. You are then encouraged to develop your own custom software in a step-by-step process. If you should find this too difficult, there are a number of ready-made examples that can be called up at the press of a button. In any case, your first working robot should be ready to go after a couple of hours of construction. After this, adding new functions is just a matter of trying them out and seeing what happens.

In the second part of this mini-series, we will look at how to program your models within the development environment.

Future prospects

Robotics Invention System version 1.5 has been available on the European market for a few months, but it has been available on the American market somewhat longer. If you visit the Lego MindStorms website, you will see that there are two extension kits listed in addition to the basic kit. These kits are called ‘Lego MindStorms RoboSports’ and ‘Lego MindStorms Extreme Creatures’. They contain parts that can be used to further dress up your robots. The ‘Lego MindStorms Exploration Mars’ kit should also be released in the near future. Complete Mars explorers can be built using this kit. Some extensions to the system, such as an infrared remote control for the robots and the previously mentioned rotary and temperature sensors, are not yet available in Europe. Let’s hope that this situation changes quickly!

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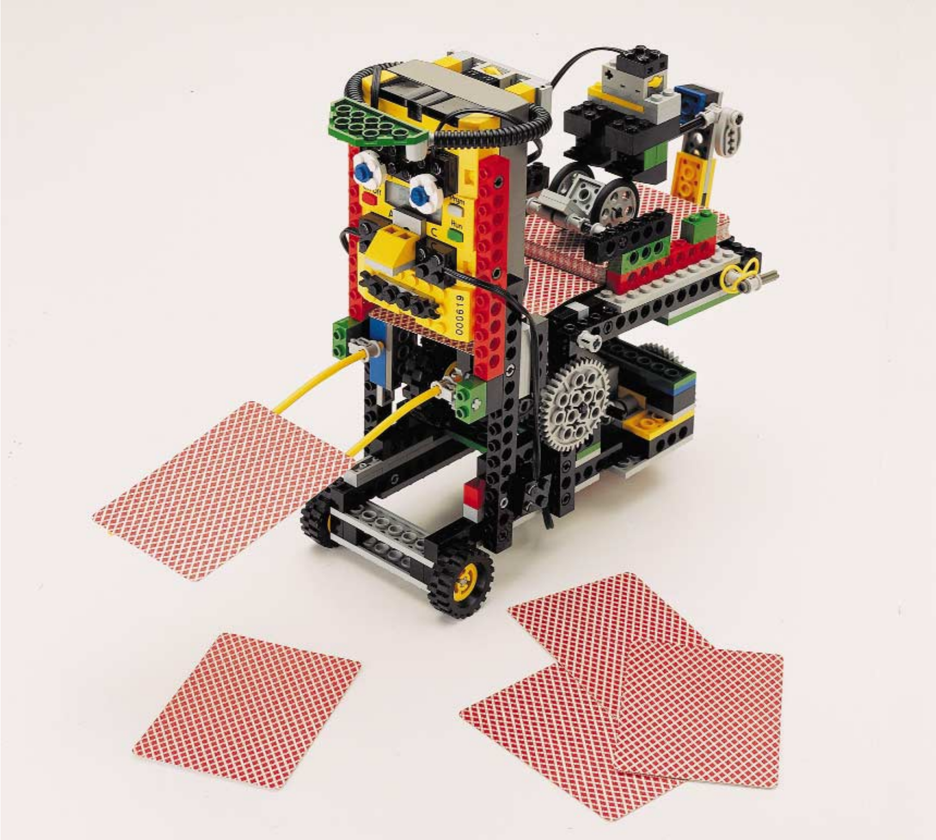

Figure 6. One of the many different robot models that can be built using the basic kit.

Figure 7. Experienced robot builders can give their imaginations free rein with this system. This robot uses no less than three intercommunicating RCX modules and is completely programmed using Visual BASIC.